

Effect of Traffic Flow on Air Quality in Hafold Air Quality Management Area

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1 Introduction

Good air quality is important to our health. People with lung disease or heart condition are risky in polluted atmosphere. However, transportation fairly contribute to the air quality while volume of traffic show gradual upward trend. The council has published the Air quality action plan, which identify the Hafold Air Quality Management Areas in Swansea. Previous research work shows that different traffic flow could have considerable effect on air quality. Investigation of traffic flow could help delivery a more accurate model to predict the pollutant concentration and make improvement in monitoring system.

This research proposal aims to evaluate the effect of traffic flow on concentration of different pollutant and to which extent traffic congestion affects the air quality in Swansea Air Quality Management Area. This research will also consider the impact of meteorology on air quality. Evaluate result and put forward some suggestions on the management of traffic congestion through the perspective of air quality.

2 Literature Review

Air Quality Management Areas (AQMA) are declared when air quality is close to or above an acceptable level of pollution. After this an Air Quality Management Area (AQMA) was declared in the Lower Swansea Valley. This is also called the Hafod Air Quality Management Area (NO₂) because NO₂ is more likely to exceed air quality objective. After declaring an AQMA the authority must prepare an Air Quality Action Plan (AQAP) within 18 months setting out measures it intends to put in place to improve air quality to at least the air quality objectives.

The Swansea council has published Air quality action plan. In this plan, it identifies the Hafold Air Quality Management Area (AQMA). **Figure 2.1** shows the general map of Hafold AQMA in Swansea.

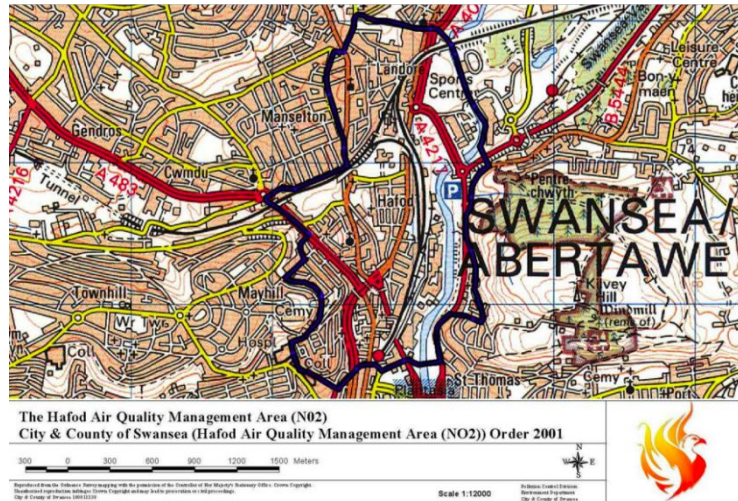


Figure 2.1 Hafod Air Quality Management Area

AQMA is a problem area by air pollution especially nitrogen dioxide. According to the research work, the NO_2 annual mean has remained consistent over the past 10 years. The result of weekly NO_2 passive study between April 2001 to March 2002 show nine of 15 monitor station were above $40\mu\text{g}/\text{m}^3$, which is the target set by Wales Air Quality. In 2017, annual nitrogen dioxide still breach target in few part of city, which may lead to the extension of AQMA.

Vehicle emission is a major resource of air pollution. **Figure 2.2** shows that UK, energy consumption in transportation is the biggest part consuming a large amount of petroleum. which accounts for more than 60%, followed by natural gas and electricity. Combustion of petroleum will produce air pollution. In each sector, the most notable trend is the growth in transport consumption and fall in industrial, which we can be reflected by increasing vehicle in Swansea. In addition, The United Kingdom is a participant of Paris Agreement. Which assumes the responsibility for reduction. The UK government has already committed to achieve zero emission in future. In terms of situation of energy in present day, UK needs to take more action in air quality management to meet that target.

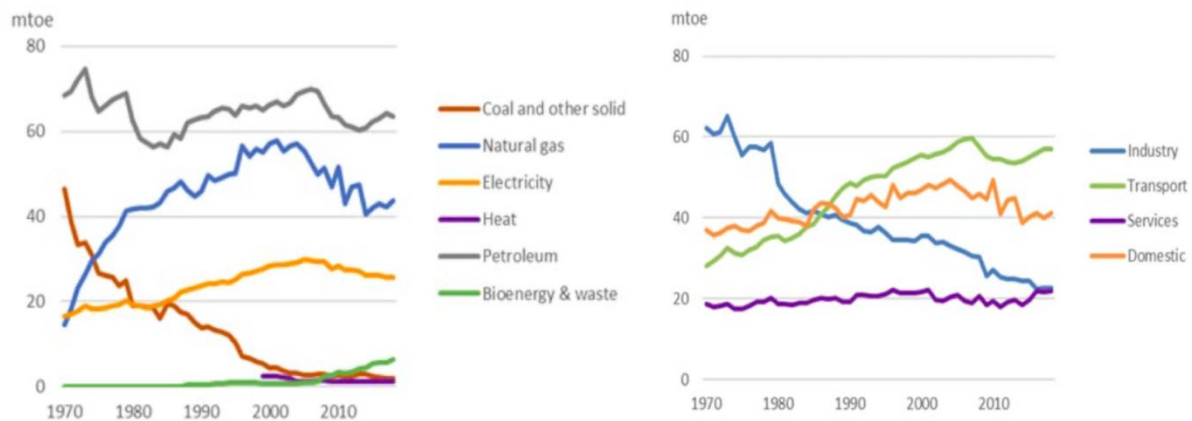


Figure 2.2 Energy Consumption in UK

With economical development and decreasing price of cars, **Figure 2.3** shows the volume of traffic in Swansea. It can be seen that vehicle mile from cars and taxis remain fairly steady while vehicle mile from all motor vehicles shows upward trend. Increasing number of vehicle miles would be risky to the air quality in Swansea. Electrical cars without exhaust still account for a small percentage of total vehicle ownership.

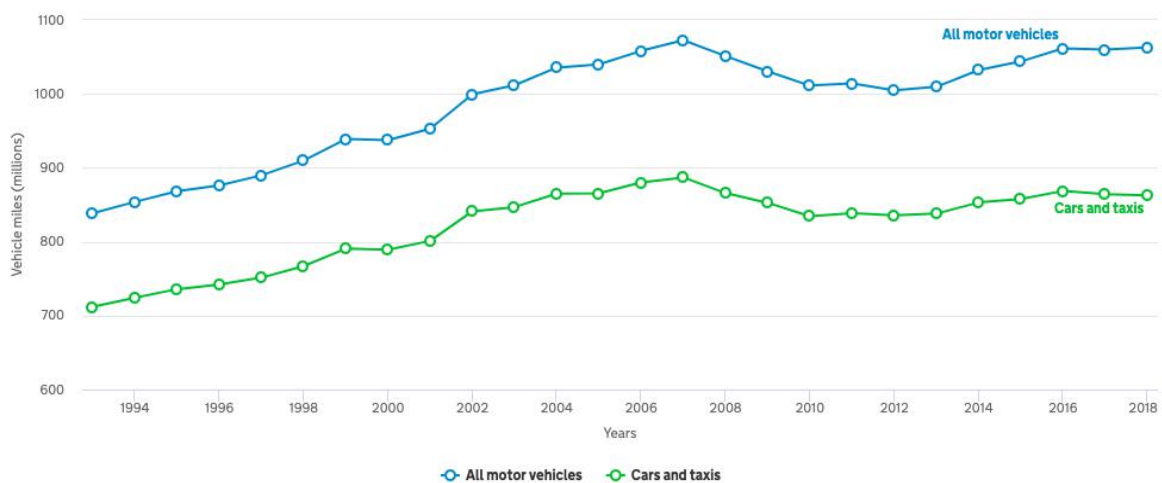


Figure 2.3 Annual volume traffic in Swansea

There are main four types of air pollutant from vehicle exhaust. Car emits carbon monoxide and hydrocarbon when fuel does not burn completely. In the process of combustion, nitrogen could react with oxygen and produce NO_x . Air pollutants emitted from cars are believed to cause lung cancer and contribute to such problems as asthma, heart disease, birth defects and eye irritation. Other environmental problem such greenhouse gas and ozone holes are also related with air pollutant. In AQMA, three types of mainly detected air pollutants are NO_2 , PM_{10} and ozone. The conclusion reach that objective for benzene, lead

and sulphur dioxide will be met and there is no further requirement for those. But there is still no air objective for ozone which is compliance with UK 8 hours mean. **Table 2.1** show some excerpt from air quality objective in regulation in Wales.

Table 2.1 Excerpt from Air Quality Objective in Regulation in Wales

Pollutant	Air quality objective	
	Concentration	Measured by
Nitrogen Dioxide (NO ₂)	200µg/m ³ less than 18 times a year	One hour mean
	40ug/m ³	Annual mean
Particulate Matter (PM ₁₀)	50µg/m ³ , less than 35 times a year	24 hours mean
	40ug/m ³	Annual mean

This Air quality action plan also pointed out that major NO₂ inputs within the lower Swansea valley are as a result of carbon emission from transportation network in AQMA. Transportation is commonly known as a resource of air pollution. In every day, car flow is variable and unsteady. Level of risk can be affected by many factors including vehicle volume, meteorology and road types. Kai (2013) used an incremental analysis to estimate pollution impacts and characterize health risks caused by congestion and suggest that traffic congestion could increase risks for individual drivers. In addition, risk from congestion can be predicable and serious. Sharad (2011) put forward under different traffic flow at two distinct junction will generate dynamic concentration of pollutant. His research examine impacts of traffic flow and meteorology on the concentration of CO, NO₂ and PM in traffic intersection. R. Smit* (2008) suggested that in order to get more accurate local emission prediction. It is important to include average speed models with congestion situation or provide congestion information in driver situation. Those analysis and research result identify likely high concentration of pollutants under different traffic flow and meteorology condition to make more accurate assessment of air quality and provide support for air quality management. it could aid to design monitoring system towards air quality system. The prediction of maximum concentration of pollutants in traffic network caused by vehicular.

In AQMA, there are several strategy towards traffic to cope with air pollution comprising enhancement of bus station, traffic checking point, emission testing and etc.

3 Research Objective

Generally, the objective of research is to investigate the effect of traffic flow on air quality condition within AQMA in Swansea with the consideration of traffic congestion and weather condition. Specifically, research objective consist of following sub-objectives.

Table 3.1 Research objective

Objective 1	Conduct correlation analysis between traffic volume and different concentration of pollutant.
Objective 1	Compare the effect of traffic volume on air quality during congestion time and off-peak time.
Objective 3	Compare the effect of traffic volume on air quality during under different weather condition and predict pollutant trajectory
Objective 4	Evaluate result and put forward some suggestions on the management of traffic congestion through the perspective of air quality.

4 Methods

The method of research generally can be divided into several steps.

Table 4.1 Steps of Research

Step 1	Set up research objectives and hypothesis
Step 2	Identify study area and time range in which monitoring stations are marked
Step 3	Collect traffic volume data including annual average daily traffic flow, count point and etc.
Step 4	Collect air quality data and meteorological data from monitoring stations

Step 5	Remove outliers and respectively establish relationship annual traffic flow and air quality over time.
Step 6	Conduct correlation analysis between traffic flow and air quality
Step 7	Study the effect of traffic congestion on air quality and how weather impact the spread of pollutant.
Step 8	Analyze result and get conclusion
Step 9	Evaluate result and put forward some suggestions

5 Results

5.1 Data Resources

5.1.1 Air quality Data

In AQMA, there are several automatic monitor sites toward air quality to provide air quality data. **Table 5.1** shows the detail in each automatic monitor station and **Figure 5.1** shows the location of automatic monitor station. In those stations, importantly, Swansea Roadside AURN, Carmarthen Road, Waun Wen is part of UK Automatic Urban and Rural Network (AURN).

Table 5.1 Automatic Monitoring Station within AQMA

Site number	Site	Site types	Pollution monitored	Measurement
CM1	Swansea Roadside AURN, Carmarthen Road, Waun Wen	Roadside	NO ₂ , PM ₁₀ , PM _{2.5}	Chemiluminescence and BAM1020

CM2	Morrison Groundhog	Roadside	NO ₂ , PM ₁₀ and Ozone	Chemiluminescence , UV Absorption and BAM1020
CM3	Cwm Level Park	Urban Background	NO ₂ , Ozone and Benzene	Chemiluminescence , UV Absorption
CM4	Hafod Doas	Roadside	PM ₁₀	Differential Optical Absorption Spectrometry
CM6	Fforestfach Cross	Roadside	PM ₁₀	EBam
CM8	Sketty Cross	Roadside	PM ₁₀	EBam
CM11	Station Court High Street	Roadside	NO ₂	Chemiluminescence
CM12	Morfa Road	Roadside	NO ₂	Chemiluminescence

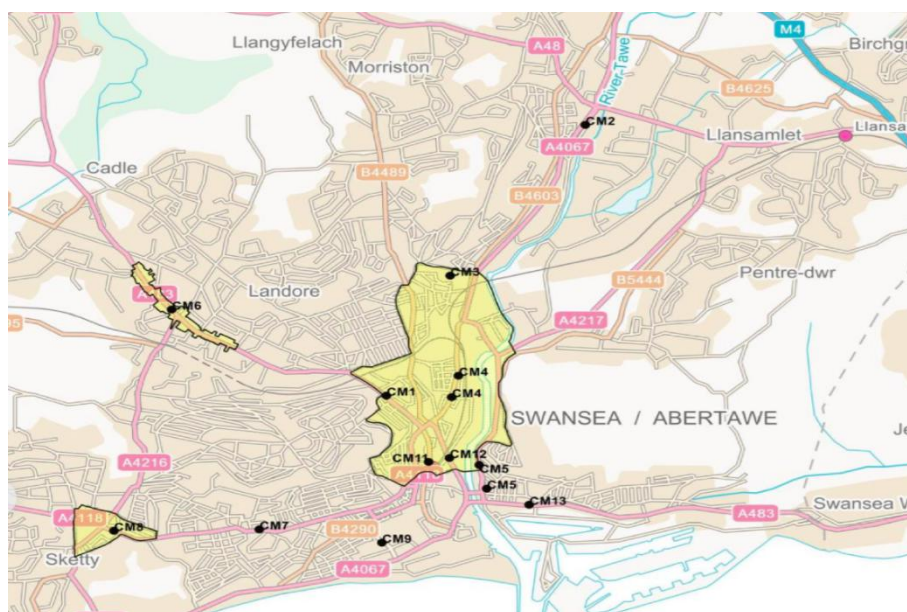


Figure 5.1 Automatic Monitor Station within AQMA

Moreover, there are 211 non-automatic stations monitoring NO₂ in 2018. Over the last years, Swansea council has been monitoring NO₂ by diffusion tube at road side with the requirement of local air quality management technical guidance. **Figure 5.2** shows the those

location of non-automatic monitor stations in AQMA. Specific information of non automatic station information could be find in **Appendix A**.



Figure 5.2 Non-automatic Monitor Station

Those monitoring stations could provide data of air pollutants and meteorological data within AQMA, which is the basic data to analyze air quality situation.

5.1.2 Traffic Flow Data

Traffic figures at the regional and national level are robust, and are reported as National Statistics. Traffic flow data mainly derive from road statistic in department of traffic. Swansea local authority could provide road statistic including count point, average annual daily traffic flow, its direction and etc. TOMTOM, a navigation system provide information from traffic to mapping technologies used by different application or website. TOMTOM website could provide traffic congestion index which could reflex the condition of traffic congestion. In addition, researchers may need to conduct field survey to record its traffic volume.

5.2 Statistical Procedures

Within AQMA, time frame of research is set in 2018. Based on the data or air quality and traffic volume, research can be conducted.

Firstly establishing the daily concentration of pollutants including NO_2 , PM_{10} and ozone in each monitoring station within AQMA. Average value of concentration of each pollutant were calculated in each hour. In order to eliminate impact of abnormal situation, statistic test and standard deviation can be conduct. within significance level of 95%, some outliers would

be removed, which calculate the upper and lower limits under certain confidence limits. A boxplot is a graph that gives a indication of how the values in the data are spread out. They have the advantage of taking up less space, which is useful when comparing distributions between many groups or datasets. Using boxplots could also help remove outliers. In addition, some date with extreme day would also be removed. Secondly, meteorological condition will also affect the spread of air pollutants which can be reflected by wind flow vector. Wind vector can tell researchers the direction of pollutant. A graph of relationship between each pollutant and wind direction will be drew. Trajectory of pollutant can be draw by comparing and analyzing wind flow and concentration of pollutant. In the same way, average value of traffic volume in each hours would be also calculated and be present in flow chart.

The correlation analysis is the next step. First of all, liner regression, correlation coefficient would be conduct between traffic volume and concentration of different pollutant. Regression analysis can be used to find a equation to describe the relationship between two variables. Different kinds of air pollutant could have different pattern with traffic volume, which can reflect the extent to which air quality is affected by traffic volume. Different kinds of pollutant may follow different pattern with traffic volume. Moreover, the traffic peak time will be compared with ordinary traffic time to investigate whether traffic congestion has more significant impact on air quality. During rush time, the concentration of air pollutant may be much higher than in normal time with same traffic volume. In peak time and off-peak time, isopleth of pollutant concentration are able to show the spread of pollutant. Isopleth can demonstrate the concentration over majority of the researched area for this time frame. Meteorology parameter including wind direction, wind speed, rainfall and temperature were used to assess whether weather condition could exacerbate air quality and which station or direction would suffer most serious condition in rush time or off -peak time. The figure of concentration with direction will be established. Those figure and wind vector could also help predict trajectory of pollutant during rush time or off-peak time. In different time, trajectory for air pollutants, concentration distribution of may be different, which be useful to the monitor and treatment of air pollutant.

6 Evaluation

The limitation of this research has some aspects. Firstly, research range aims at Hafold Air Quality Management Area rather whole urban area in Swansea. There are still large area of urban area. Secondly, it is tough to detect how much percentage air pollution in atmosphere.

actually come from vehicle exhaust because many human activities could have impact on air quality. Industrial emission and combustion in household and etc could also produce large amounts of air pollutant. Even people who don't drive when they buy goods and services that also involve combustion of fuel or air pollutant emission. In this study, in order to reduce the impact from other factor and focus on traffic flow, outliers value and emergency situation are removed out of research by statistical testing. Moreover,

This research work may have some proposed impact. First of all, this research maybe useful in the management of traffic. It can assess the extent to which change of traffic flow impact on air quality and risk human health. This research work can provide some evidence into other city with serious traffic congestion problem. Many cities around world suffer from traffic congestion problem which also leads to air pollution problem. Assessing effect of traffic congestion on air quality may be useful to find seriously affected area and to recognize the road network in city. Specifically, different air pollutant with different property would follow different pattern, which provide support for reduction of air pollutant because of treatment methods for air pollutant are varied. It could also assess whether traffic congestion could have more serious effect on air quality compared with off-peak time. If traffic congestion would have more significant impact on air quality, authority needs to consider more improvement on traffic network. This research would also predict trajectory of air pollutant under traffic congestion and off-peak time to find the affected area by emission exhaust. Establishing isopleth graph are able to identify maximal or minimal concentration of different pollutant and help establishment of monitoring stations.

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Appendix

Appendix A Non-automatic monitoring stations within AQMA

Site Number	Site Type	Site Height (m)	OS Grid Reference	
			X	Y
5	Roadside	3	262548	192943
6	Roadside	3	262612	192995
7	Roadside	3	262691	192852
8	Roadside	3	262990	195820
10	Roadside	3	263219	195513
11	Roadside	3	263344	195474
12	Roadside	3	263680	195103
18	Roadside	3	265526	195807
19	Roadside	3	265597	194061
20	Roadside	3	265594	194175
21	Roadside	3	265682	195374
22	Roadside	3	265728	195494
23	Roadside	3	265876	194318
24	Roadside	3	265922	194428
25	Roadside	3	265973	195222
26	Roadside	3	265526	195807
27	Roadside	3	265597	194061
29	Roadside	3	265594	194175
59	Roadside	3	265918	194463
63	Roadside	3	262675	192775
64	Roadside	3	262719	192840
65	Roadside	3	262735	192855
66	Roadside	3	262802	192829
67	Roadside	3	265903	193683
83	Roadside	2	262785	192838
84	Roadside	2	262714	192839
85	Roadside	2	262702	192847

86	Roadside	2	262704	192865
87	Roadside	2	262697	192798
88	Roadside	2	262605	192916
89	Roadside	2	262587	192956
90	Roadside	2	262631	192996
91	Roadside	2	262534	192950
97	Roadside	2	262946	195902
98	Roadside	2	263142	195548
99	Roadside	2	263387	195332
121	Roadside	2	265706	193662
135	Roadside	5	262605	192916
136	Roadside	5	262612	192995
137	Roadside	5	262631	192996
244	Roadside	3	265466	194930
245	Roadside	3	265448	194922
247	Roadside	3	265394	194899
249	Roadside	3	265326	194871
251	Roadside	3	265263	194845
275	Roadside	3	265658	194856
276	Roadside	2	265610	194871
277	Roadside	2	265596	194875
278	Roadside	2	265573	194882
279	Roadside	2	265555	194926
280	Roadside	2	265542	194980
281	Roadside	2	265542	194872
282	Roadside	2.5	265540	194840
287	Roadside	2.5	265555	194926
288	Roadside	2	265542	194980
289	Roadside	2	265542	194872
347	Roadside	2	265562	193518
348	Roadside	2	265572	193549
349	Roadside	2	265578	193576

350	Roadside	2	265577	193606
393	Roadside	2	262620	192740
394	Roadside	2	262445	192645
395	Roadside	2	262413	192630
396	Roadside	2	262370	192609
402	Roadside	2	265907	193721
406	Roadside	2	265973	195222
407	Roadside	2	265539	195664
424	Roadside	2	265536	194752
425	Roadside	2	265509	194748